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New Products and Technologies, Based on Calculations Developed Areas

Following statistics, currently prosperous and have high GDP / capita, only countries that have and fructify intensively large natural resources and/or produce and export products massive based on patented inventions accordingly. Without great natural wealth and the lowest GDP / capita in the EU, Romania will prosper only with such products. Starting from the top experience in the country, some patented, can develop new and competitive technologies and patentable and exportable products, based on exact calculations of developed areas, such as that double shells welded assemblies and plating of ships' propellers and blade pump and hydraulic turbines.

Keywords: *invention, developed area, welded assembly, plated blades.*

1. Introduction

The economic production and living standards have increased dramatically in developed countries, but using unsustainable limited resources. However, the world population has exceeded 7 billion and further increase. And every man has the right to acquire and act like a high standard of living. But if everyone in the world would equal the current average consumption per capita in developed countries, would not reach the earth's resources. The solution is not stopped growth, but must be produced more efficiently and replaced, reused, repaired and recycled what is produced [1]. This is possible only realizing innovative new technologies and products.

For the last six years for which data have been published [2], are played in Table 1, for the EU and other countries considered in descending order of gross domestic product per capita GDP / capita in 2012: (PIB/loc in Romania)

- WON (NOM in Romania) world order number from the list of world countries, in descending order of GDP / capita;
- The absolute value of GDP / capita (in $)

- The relative value of GDP / capita (expressed in % of the EU average).

From Table 1 it follows that, since joining the EU, Romania was always the last place in the EU as an absolute value of GDP / capita, as the relative value of GDP/ capita increased by only 1% (from 34% to 35% from the EU average) and world ranking lost 12 positions (WON from 90 to 102). Recovery only solution is massive production and export of competitive and patented products, markets as widely useful. Or, by 2030, the global urban population will increase from 3.2 to 4.7 billion; only China will have additional 400 million new city dwellers and India - 215 million [3]. The need for various products, including efficient installations for new townsfolk, develops a huge market. To occupy as much and as cost of it, under fierce international competition, autochthonous competitive original technical solutions, which may be useful new city dwellers, must be rapidly credible by application in country and protected by international patents for inventions.

2. Explanation of modest economic development of Romania

Following statistics, currently countries prosperous only if have and fructify intensively large natural resources and/or produce and export products massive based on patented inventions accordingly.

It is so because these patents protecting original technical solutions that made the products competitive (works, services and / or products) generate prosperity where maintained, are profitable, growing and / or creates production units and jobs to deliver these products. Inventive annual performance of a country is expressed by the specific number of the patent, or the number of patents obtained per million inhabitants per year. If country A, with a number of inhabitants NI, get in NY years on the B market a total number of patents TNP, the average number of the A country's patent SNP on the market B:

$$SNP = 1.000.000 \times TNP / (NI \times NY)$$

For EU countries and other countries in descending order of GDP / capita in 2011, considering the number of inhabitants NI [4], the number of U.S. patents [5] and the number of patents issued by the European Patent Office - EPO [6], is calculated in Table 2, for the long-time, average specific patent number SNP and report SNP / SNP_{RO} (where SNP_{RO} is Romania SNP) both for U.S. patents and European patent.

i.	Anul	2007			2008			2009			2010			2011			2012		
	Ţara	NOM	PIB/loc		NOM	PIB/loc		NOM	PIB/loc		NOM	PIB/loc		NOM	PIB/loc		NOM	PIB/loc	
			Mii $	% UE		Mii $	% UE		Mii $	% UE		Mii $	% UE		Mii $	% UE		Mii $	% UE
1.	Luxemburg	1	80,8	246	3	81,2	241	3	78,0	239	3	81,8	249	3	84,7	249	5	80,7	234
2.	Austria	17	39,0	119	21	40,4	120	21	39,4	121	21	40,3	122	18	41,7	123	21	42,5	123
3.	Olanda	19	38,6	117	20	40,5	120	22	39,2	120	19	40,5	123	17	42,3	124	24	42,3	123
4.	Suedia	25	36,9	112	25	38,2	113	28	36,8	113	24	39,0	119	21	40,6	119	25	41,7	121
5.	Irlanda	10	45,6	139	11	45,5	135	16	42,2	129	28	37,6	114	24	39,5	116	26	41,7	121
6.	Germania	31	34,4	105	33	35,5	105	37	34,1	105	31	35,9	109	29	37,9	111	29	39,1	113
7.	Belgia	26	36,5	111	27	37,5	111	29	36,6	112	26	37,9	115	30	37,6	111	31	38,1	110
8.	Danemarca	24	37,4	114	30	37,2	110	31	36,0	110	29	36,7	112	23	40,2	118	32	37,7	109
9.	Anglia	28	35,3	107	32	36,7	109	34	35,2	108	35	35,1	107	34	35,9	106	36	36,7	106
10.	Finlanda	27	35,5	108	31	37,0	110	36	34,9	107	34	35,3	107	26	38,3	113	37	36,5	106
11.	Franţa	33	33,8	103	39	33,3	99	40	32,8	101	39	33,3	101	35	35,0	103	40	35,5	103
	Media UE	37	32,9	100	38	33,7	100	41	32,6	100	41	32,9	100	38	34,0	100	42	34,5	100
12.	Spania	35	33,7	102	36	34,6	103	38	33,7	103	48	29,5	90	43	30,6	90	47	30,4	88
13.	Italia	39	31,0	94	41	31,4	93	44	30,3	96	43	30,7	93	45	30,1	89	48	30,1	87
14.	Slovenia	46	27,3	83	47	29,6	88	50	27,9	86	50	28,4	86	46	29,1	86	52	28,6	83
15.	Cehia	51	24,4	74	51	25,9	77	52	25,1	77	53	25,6	78	52	25,9	76	55	27,2	79
16.	Cipru	47	27,1	82	58	21,3	63	58	21,2	65	62	21,0	64	47	29,1	86	56	26,9	78
17.	Malta	52	23,2	71	52	24,6	73	54	23,8	73	54	25,1	76	53	25,7	76	58	26,1	76
18.	Grecia	40	30,5	93	40	32,1	95	43	32,1	98	44	30,2	92	49	27,6	81	62	25,1	73
19.	Slovacia	60	19,8	60	55	22,0	65	59	21,2	65	57	22,2	67	57	23,4	69	63	24,3	70
20.	Portugalia	55	21,8	66	54	22,2	66	57	21,8	67	56	23,0	70	58	23,2	68	64	23,0	67
21.	Estonia	56	21,8	66	57	21,4	64	62	18,7	57	63	19,0	58	62	20,2	59	66	21,2	61
22.	Polonia	69	16,2	49	71	17,4	52	68	17,9	55	65	18,8	57	63	20,1	59	67	21,0	61
23.	Lituania	68	16,7	51	69	17,8	53	72	15,4	47	70	15,9	48	66	18,7	55	70	20,1	58
24.	Ungaria	63	19,5	59	63	19,8	59	63	18,6	57	64	19,0	58	64	19,6	58	71	19,8	57
25.	Letonia	66	17,7	54	72	17,3	51	79	14,5	44	81	14,3	43	80	15,4	45	75	18,1	52
26.	Croaţia	71	15,5	47	72	16,1	48	69	17,6	54	67	17,5	53	67	18,3	54	74	18,1	52
27.	Bulgaria	88	11,8	36	86	12,9	38	89	12,6	39	89	12,8	39	91	13,5	40	94	14,2	41
28.	România	90	11,1	34	90	12,2	36	96	11,5	35	96	11,5	35	97	12,3	36	102	12,8	35
	Singapore	8	48,9	149	9	52,0	154	8	50,3	154	6	57,2	174	5	59,9	176	7	60,9	177
	Norvegia	5	55,6	169	7	55,2	164	5	58,6	180	5	59,1	180	8	53,3	157	10	55,3	160
	Elveţia	15	39,8	121	17	40,9	121	19	41,7	128	16	42,9	130	15	43,4	128	11	54,6	158
	Hong Kong	14	42,0	128	14	43,8	130	15	42,7	131	11	45,6	139	10	49,3	145	13	50,7	147
	SUA	9	46,0	140	10	47,0	139	11	46,4	142	10	47,4	144	12	48,1	141	15	49,8	144
	Australia	23	37,5	114	26	38,1	113	23	38,8	119	18	41,3	126	19	40,8	120	22	42,4	123
	Canada	21	38,2	116	21	39,3	117	27	38,4	118	23	39,6	120	22	40,3	119	27	41,5	120
	Taiwan	42	29,8	91	40	31,9	95	47	29,8	91	36	35,1	107	28	37,9	111	30	38,5	112
	Japonia	34	33,8	103	36	34,2	101	42	32,6	100	38	34,2	104	37	34,3	101	38	36,2	105
	Coreea de Sud	50	24,6	75	52	26	77	49	28,0	86	45	30,2	92	40	31,7	93	43	32,4	94
	Israel	43	28,8	88	49	28,2	84	48	28,4	87	47	29,5	90	41	31,0	91	44	32,2	93
	Noua Zeelandă	45	27,3	83	50	27,9	83	51	27,3	84	51	28,0	85	48	27,9	82	50	28,8	83
	Rusia	75	14,6	44	74	15,8	47	75	15,1	46	71	15,9	48	70	16,7	49	76	17,7	51
	Turcia	99	9,4	29	93	12,0	36	98	11,2	34	94	12,3	37	86	14,5	43	91	15,0	43

Table 1.

Although annual won dozens of medals at international invention salons from Geneva in Table 2 and the updated data [2], [4], [5], [6] results that every million inhabitants, Romania has chronically very few international patents, namely U.S. patents in the years 1963 - 2011 for 32 times less than the world average and 74 times less than the EU average (but only 35 times less than the EU average in 2012) and the European Patent in 1999 - 2011 to 400 times less than the EU average and 59 times less than the world average, and especially because of this, exports too little and too less profitable and therefore has the lowest GDP / capita from EU (being in the world the 90th in 2007 and 2008 and falling at 102 in 2012) and a reduced standard of living.

Romania can prosper following the example of South Korea, from 13 U.S. patents in 1978, arrived in 2012 to more than 13,000 U.S. patents and GDP / capita = $ 32.400 (held 43 world) than the EU average of 34.500 $ (instead of 42 world).

So for sustainable economic growth, Romania's only solution is to increase the number of international patents for invention and exploiting them international. This growth can begin in pumps and hydraulic turbines [7-9], but it can only increase the level needed by law, co interest for and empowering material economic decision makers at all levels (to ensure timely fruition of autochthonous inventions) and awareness of the entire population of the country (to provide training, affirmation and enjoyment of all talents in the country, including the inventor).

Table 2.

The country	**GDP/ capita in 2011 thousands $**	**U.S. Patent in 1963-2011**			**European patent in 1999-2011**		
		TNP= total patents	**SNP = specific number of patents**	$\frac{SNP}{SNP_{RO}}$	**TNP= total patents**	**SNP = specific number of patents**	$\frac{SNP}{SNP_{RO}}$
Luxembourg	84,7	1081	43,33	94	1134	171,35	1391
Netherlands	42,3	42792	52,19	114	20272	93,20	756
Austria	41,7	16959	42,10	92	6947	65,01	527
Sweden	40,6	44736	100,28	219	16279	137,55	1116
Denmark	40,2	12062	44,40	97	5427	75,30	611
Ireland	39,5	3225	13,93	30	1434	23,36	189
Finland	38,3	17228	66,80	146	8183	119,60	970
Germany	37,9	346360	86,93	190	148978	140,94	1144
Belgium	37,6	18730	36,61	80	6738	49,65	403
England	35,9	141439	45,78	100	25592	31,22	253
France	35,0	129254	40,19	88	51279	60,10	488
The EU average	34,0	840094	34,02	74	322786	49,28	400
Spain	30,6	7355	3,19	7	3858	6,30	51
Italy	30,1	51375	17,11	37	24265	30,46	247
Slovenia ***	29,1	288***	9,01	20	283	10,90	88
Cyprus	29,1	49	0,87	2	143	9,66	78
Greece	27,6	668	1,79	4	258	1,84	15
Czech ***	25,9	571***	3,31	7	344	2,60	21
Malta	25,7	36	1,79	4	91	17,08	138
Slovakia **	23,4	94***	1,07	2	81	1,13	9

Portugal	23,2	353	0,66	1	272	1,94	15
Estonia ***	20,2	63***	3,08	7	40	2,41	19
Poland	20,1	1028	0,54	1	265	0,53	4
Hungary	19,6	3108	6,36	14	497	3,83	31
Lithuania ***	18,7	62***	1,09	2	10	0,21	2
Latvia ***	15,4	29***	0,82	2	32	1,12	9
Bulgaria	13,5	658	1,90	4	49	0,53	4
Romania	12,3	491	0,45	1	35	0,1232	1
USA	48,1	2837050	184,48	402	156701	38,40	311
Switzerland	43,3	58828	156,82	342	25528	256,50	2082
Japan	34,3	852321	136,56	298	123132	74,36	603
Republic of Korea	31,7	90662	37,86	83	8861	13,95	113
The world average	12,0	4992192	14,55	32	666885	7,32	59

*** For 6 countries, U.S. patent was considered only time since independence state.

3. Developed surfaces

From a mathematical perspective, the movement in space of a line segment generates surfaces ruler. Not all areas rulers are deployed. For example, cooling towers hyperboloid-shaped are ruler surfaces not developed. A ruler surface is developed if it satisfies a certain differential equation. Thus, in a reference system triortogonal x0yz is ruler surface with the equation:

$$z = f(x, y) \tag{1}$$

This area is developed if it satisfies the equation:

$$\frac{\partial^2 z}{\partial^2 x^2}\frac{\partial^2 z}{\partial^2 y^2} = \left(\frac{\partial^2 z}{\partial x \partial y}\right)^2 \tag{2}$$

For shells of spiral chambers (SC) of some hydraulic machines, equation (2) was considered for a long time [10] and was used along with the mathematics of geodesic (minimum distance, belonging to a curved surface, between two points on the curved surface) including the development of a patented process [11] successfully applied since 1976 at all Francis turbines and some Kaplan turbines manufactured in Machine Building Works - UCM Resita and mounted in Romania or exported and at the all large pumps with aspiration elbows (AE) and / or the SC welded, supplied by SC AVERSA S.A. Bucharest.

At the turbines exported, all AE and some SC were produced by locally subcontractors as design and technology from Romania (Fig. 1).

Foreign literature, namely the U.S., only later mentions such elements [12], checked only on physical models, so industrial unapplied.

Exact calculation of the developed areas provides competitive products and technologies, some already made, patented [11] and exported for decades, while others apply to higher production are achievable in Romania, World Premiere, export and international patents.

4. Assemblies welded from double shells/shells

Works [8], [9] presents mathematical modeling for a new technical solution advantageous embodiment of welded assemblies, namely spiral chambers (SC) and aspiration elbows (AE) with oval section of hydraulic machines and the parties angles of armored adduction of hydropower plant (HPP). All of them are made of shells and the calculation of each shell requires:

- The calculation of contour of developed shell (for cutting sheet shell);
- Calculating the number n_t (especially convenient technology) bending lines, spread relatively evenly over the entire shell surface.

If bending lines coincide with the surface deployable generators, ensure proper bending of shell. By pressing successively on the bending lines, the shell curves and gets necessary spatial form, i.e. its outline spatially contour overlap neighboring parts, which can weld so easy.

a

b

Figure 1. Aspiration elbow made in Turkey, after UCMR project for Kapulukaia hydropower plant. a. Side view b. View from downstream.

Accurate calculations of shells provide easy implementation of these assemblies' current solutions and a new solution, namely assemblies of double shells.

Centrifugal and diagonal pumps with flows and medium to large powers, and Francis and Kaplan turbines with metal SC and / or metal AE, have optimum duration of continued operation larger and smaller rehabilitation costs (by restoring function and replace only the rotor) if SC and AE have on interior surface a roughness which is maintained very small for very long time, which it is ensures at the pump by coatings, egg ceramitech [13], or by a new methods, with SC and AE made of double shells [8].

Each double shell containing an outer shell and an inner shell.

Outer shell adopt usual sheet, easy to weld, thickness necessary to retrieve all the mechanical requests generated by design pressure of the pump or turbine, including water hammer.

Inner shell is adopted of thin sheet anti abrasive and / or anti-corrosive, with roughness that maintains low as long as possible. It is resistant to possible cavitations phenomena, at abrasion and / or corrosion and provides a high performance, due to the small roughness.

So the new solution increases performances and resistance to physical wear.

Exact calculation of bending lines and correctly bent of both shells provide the necessary precise molding of the inner shell inside the outer shell.

For each shell, exact calculation contains two sequential stages, namely:

- Determination of the unique developed surface which is based on two plane curves that bordering the shell (considered average fiber);

- Calculation of the contour of developed shell and the calculation of bending lines.

Obviously, very large volume of calculations is made on computer.

5. Implementation of the site of large welded assemblies

The same combination of mathematical and technological elements offers other new technical solutions [8], [9]. Thus, at hydropower plant with turbine (Francis and Kaplan) with large metal SC and / or AE, these SC and AE, and adduction armored, can be made of single or double shells (while maintaining high performances) directly on the site HPP. Current making of these assemblies in specialist workshops, away from the site, present disadvantages, as follows:

- Transport expensive, sometimes at great distances, of some large assemblies;
- To ensure the stability of these assemblies form during transport, it is necessary hardening their expensive;
- Very large spiral chambers, which must be subjected to pressure testing after manufacture, must be made of several pieces, which, in order to removable assemble, require expensive additional flanges.

Disadvantages are removed making assemblies on the HPP site, where carrying only sheet and machinery for cutting, bending and welding of shells.

6. Technologies of partial replacement of some expensive materials

Environment and aggressive operating conditions require the adoption of some parts expensive or very expensive materials. In some of these cases, as the ship propellers and rotors of hydraulic machines (Hydraulic turbines type Francis, Kaplan and bulb and centrifugal, diagonal or axial pumps), aggression occurs only on the surface of the parts. In these cases, is economically attractive the adoption of the parts of the usual material, cheap, covered only at surface with an expensive material, to provide sufficient resistance to the aggressive environment. In case of rotors of large Francis turbine, the industry in the former Soviet Union also had achievements, including for turbines with unitary power of hundred of MW, which decreased the cost price by 60% ago still 4-5 decades. These rotor blades were made of usual table, cheap, adequate thickness, and cut to gain an appropriate shape, then were placed on both sides with thin sheets with high resistance to aggressive conditions specific environment within which the rotors Francis works. Joining necessary thin sheet, of surface, at the sheets thick base ensured using compression technologies by explosive. After joining the entire contact surface between the sheets, these elements were bent flat and were assembled with crowns rotors by welding. Thus, there were obtained Francis plated rotors, much lower cost, with adequate resistance to the aggressive environment in which it must operate. In time, they demonstrated shortcomings and were given to this solution.

At centrifugal pumps, surfaces in contact with the pumped fluid (of the spirals chamber, aspiration elbow and of the impeller), sometimes covered with a protective layer, such ceramitech [13], especially to get smooth surfaces with very small roughness in order to increase the performance. However, in time, this layer is degraded faster than the plated sheets.

Apart from plated Francis rotors (solution given up) and in the case of pumps, of coating with protective layers less resistant in time, in the world does not even know the other achievements or ongoing research to achieve the impellers of hydraulic machinery, with only expensive materials on the surface in contact with the aggressive environment.

Of hydraulic axial machinery blades (naval propellers, rotor blades of Kaplan and bulb turbine and the axial pumps) have double curve and variable thickness and thus increase the difficulties of cheap achieving, with expensive material only to the surface in contact with the aggressive liquid medium. Technology (abandoned) of plating from Francis impellers is obviously impossible in the case of hydraulic axial machinery blades. This may explain the absence, in the world, of the achievement of hydraulic axial machinery blade coating.

On the other hand, nationally and globally, the total tonnage and number of ships propeller, Kaplan and bulb turbines and axial pumps, often exceeds the total tonnage and number of turbines Francis, both in existing machines and in operation, as well as to be produced in the future. And the materials from that are executed marine propellers because of increased aggressiveness of marine salt water are the most expensive; these propellers are executed either from special alloy steel or alloy most expensive, without iron, only Ni, Cu and Al. So replacing expensive materials to achieve exclusively with the realization of cheap material but plated (through new technology, absolutely different from the Francis impellers), would provide both national and global level economies more larger in impellers domain of axial hydraulic machines than the economies achieved by plating the Francis impellers.

In the new technology, the whole area vulnerable of blades has split into developed strips from a mathematical perspective, conveniently arranged in the hydraulic perspective. These strips can properly processed only by cutting and machine tools with numerical command (MTNC) with 5-axis independent mechanic with special tools that can generate surfaces whose rulers and design, in order to process all the strips must take into account the MTNC geometry. Each strip deployed will be plate with a thin sheet, resistant to aggressive environments, folded properly, by press bending successive lines which should coincide with generators deployable plated surface. The adhesion required of operation resistant plating can be provided, for example, by an adhesive layer with constant and small thickness, it is one of the reasons why the base material to be machined with high precision, on the entire area of the developed surfaces, and plated sheets must be cut and folded with great precision.

Must be designed and implemented tools which, used on a MTNC with 5-axis and considering the geometry of this MTNC, can generate surfaces ruler.

It is noted that in order to enhance adhesion, the surfaces in contact with the adhesive is good to be rough. By cutting, resulting rough surface of the base material and the surface of the plated panels can be prepared for this purpose.

It is worth mentioning the fact that the basic material for coating as usual steel, it can be more easily cutting than the chip alloy steels with Cr and Ni, which is usually, made the hydraulic axial machines blades.

Risk occurs, the base material is less resistant than alloy steel or CuNiAl used before, and sometimes the blades will be designed with larger thickness, resulting in heavier blades. Since the case must be determined whether this shortcoming can be compensated by design.

In 1984 Machine Building Works Resita - UCMR, put into operation a MTNC with 5 mechanical independent axes (3 linear axes X, Y, Z and 2 angular axes B, C), produced in collaboration UCMR and German companies Waldrich - Coburg and Siemens [14]. Is a milling machine with an batiu long of 11 m, 4.5 m wide and with a two rotary milling head, oscillating both vertically and horizontally, having a maximum tool diameter of 160 mm and an accuracy of 2 microns (Fig. 2). The technology of processing blades with all software package very complex calculation was done entirely in Romania [15], [16], [17].

Figure 2. Working at UCMR of one blade on MTNC with 5-axis

Other MTNC with 5-axis lower and other types, products in Japan, namely France, has equipped in Romania the shipping industry (in Galati) and aircraft manufacturing industry (Bucharest).

For the world's largest hydropower plant (Three Gorges - China), inaugurated in 2009, the rotor blades of some of the 26 Francis turbines of 700 MW each were conducted in Bucharest Heavy Machinery Enterprise - BHME.

All these elements ensure Romania's experience and expertise to make even the world's first plating technology of hydraulic axial impellers blades.

However, the generation of deployable surfaces through 5-axis machining on MTNC could be effective in other areas, such as molds for automobiles for processing, in some cases, could significantly reduce the cost of the components of the bodyworks by reduction the number of the molding need to replace several smaller molding with fewer molds higher.

Also, the plating can be expected in the shipping industry, namely the construction of the hull, and the development of naval equipment in order to improve performance. Hull surface is achieved currently with some technological difficulties shaping sheet and in exploitation is subject to corrosion, electrolyte erosion and vegetation aggression and marine crustaceans that embed the table, increasing their roughness, thereby increasing drag the ship and fuel consumption.

7. Conclusions

1. In order to facilitate maintenance and to maintain high performance, at the aspiration elbows welded and welded spiral chambers of the turbines and hydraulic pumps, as well as of hydropower plants metal feed pipe, it may take the embodiment of double shells. Each double shell has an exterior shell of usual sheet, adequate thickness, that take all mechanical efforts and inside a shell of thin and shiny stainless steel sheet resistant to corrosion and / or erosion and which, keeping long time very low roughness, maintaining high performance. This solution is based on complex calculations [8], [9] and the technological elements have been used for decades, some of which are patented [11].

2. The same combination of mathematical and technological elements offers other new technical solutions [8], [9]. Thus, hydropower plants (HPP) with large or very large turbines and with metal SC and / or AE, these SC, AE and armored adduction can be manufacture from simple or double shells directly on the HPP site, thus avoiding the disadvantages existing solution for manufacturing of these great welded assemblies in workshops, site distant from HC.

3. It reduces the cost price of marine propellers and rotor blades of pumps and axial hydraulic turbines by plating them. Working successfully in 1984, on MTNC with 5-axis independent mechanical, of Kaplan and bulb impellers blades in Resita, of marine propellers in Galati and of airplane parts in Bucharest and Francis rotor blades achieve for the bigger HPP in the world, provides Romania experience and expertise to make even the world's first plating technology of hydraulic axial rotor blades and generate on deployable surfaces, efficient in other areas, by cutting machining on the MTNC with 5-axis.

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